REMARKS

Claims 1-31 remain pending in this application. The attached Appendix includes marked-up copies of each rewritten paragraph (37 C.F.R. §1.121(b)(1)(iii)).

In response to the Notice of Incomplete Reply mailed January 4, 2002, this Preliminary Amendment is submitted to eliminate references to Fig. 18. This Amendment is submitted without prejudice to resubmission of Fig. 18 during prosecution of this application. It is respectfully submitted that reinsertion of Fig. 18 will not introduce new matter because the subject matter of Fig. 18 is adequately described in the present specification at pages 2-3 and 5-9.

Respectfully submitted,

James A. Oliff
Registration No. 27,075

Thomas J. Pardini
Registration No. 30,411

JAO:TJP/can

Attachment:
Appendix

Date: January 25, 2002

OLIFF & BERRIDGE, PLC
P.O. Box 19928
Alexandria, Virginia 22320
Telephone: (703) 836-6400

DEPOSIT ACCOUNT USE AUTHORIZATION
Please grant any extension necessary for entry; Charge any fee due to our Deposit Account No. 15-0461

APPENDIX

Changes to Specification:

The following are marked-up versions of the amended paragraphs:

[0005] The known technique for improving the thermal stability of the magnetic disk, especially a magnetic disk having magnetization in the in-plane direction include a method in which a so-called keeper layer having soft magnetization is provided as an underlying base layer for a recording layer, and a method in which a layer having magnetization in a direction opposite to that of magnetization of a recording layer is provided. As one of the latter method, a technique is disclosed in a literature of E. N. Abarra et al. (E. N. Abarra et al., TECHNICAL REPORT OF IEICE. MR2000-34 (2000-10))~~as shown in Fig. 18~~, in which the thermal stability is improved by forming an Ru thin film as a magnetic coupling layer between a recording layer of CoCrPtB and a magnetization-stabilizing layer of CoCrPtB of a magnetic disk. In the structure of the magnetic disk~~shown in Fig. 18~~, when the Ru layer having a thickness of about 0.5 to 1 nm is allowed to intervene as the magnetic coupling layer between the recording layer and the magnetization-stabilizing layer, the exchange coupling is effected in an antiferromagnetic manner between the recording layer and the magnetization-stabilizing layer. Therefore, the layers have antiparallel magnetization, and hence the magnetization of the recording layer is stabilized by the magnetization-stabilizing layer. It is described in this literature that the antiferromagnetic exchange coupling effected by the Ru layer further thermally stabilizes the magnetization of the recording layer, making it possible to improve the recording and reproduction characteristics of the magnetic disk.

[0012] As a result of repeated investigations performed by the present inventors in order to further improve the magnetic disk having the conventional type structure~~shown in Fig. 18~~, it has been found out that the exchange coupling force, which is generated between

the ferromagnetic atom-rich layer and the recording layer, is remarkably raised by forming the ferromagnetic atom-rich layer formed with the material having the high ferromagnetic atom concentration as compared with the ferromagnetic material for forming the recording layer, in place of the magnetization-stabilizing layer. The exchange coupling force, which is generated between the ferromagnetic atom-rich layer and the recording layer as described above, is larger than the exchange coupling force which acts between the recording layer and the magnetization-stabilizing layer of the magnetic disk having the conventional type structure~~ shown in Fig. 18~~. As described above, the strong exchange coupling force is generated between the recording layer and the ferromagnetic atom-rich layer, and hence it is possible to stabilize the magnetization of the recording layer. Therefore, the thermal stability of the recording layer is further enhanced as compared with the conventional magnetic disk~~ shown in Fig. 18~~, making it possible to realize further advanced high density recording. In the present invention, the term "ferromagnetic atom" means the element which exhibits the ferromagnetic property in the form of simple substance. Specifically, the ferromagnetic atom includes cobalt (Co), nickel (Ni), and iron (Fe).

[0013] The ferromagnetic atom-rich layer is formed with the ferromagnetic material which has the high ferromagnetic atom concentration as compared with the ferromagnetic material for forming the recording layer. For example, when the recording layer is formed of a ferromagnetic material containing Co, Ni, or Fe, the ferromagnetic atom-rich layer can be formed of a ferromagnetic material containing a ferromagnetic atom such as Co, Ni, and Fe at a higher concentration as compared with the recording layer. The ferromagnetic atom-rich layer can be also formed of a metal simple substance such as Co, Ni, and Fe or CoNiFe alloy. Alternatively, the ferromagnetic atom-rich layer may be formed of an alloy containing a transition metal and Co, Ni, or Fe. In this case, the transition metal may be a noble metal such as Pt, Au, Ag, Cu, and Pd. In the present invention, when the ferromagnetic atom

concentration of the ferromagnetic material for constructing the ferromagnetic atom-rich layer is higher than the ferromagnetic atom concentration of the magnetic material for constructing the recording layer, it is possible to obtain the effect to enhance the exchange coupling force generated between the ferromagnetic atom-rich layer and the recording layer. However, in order to obtain a sufficient effect in view of the results obtained in the embodiments as described later on, it is desirable that the ferromagnetic atom concentration of the ferromagnetic material for constructing the ferromagnetic atom-rich layer is higher than the ferromagnetic atom concentration of the ferromagnetic material for constructing the recording layer by not less than 19 % as represented by an absolute value. Especially, it is desirable that the ferromagnetic atom concentration of the ferromagnetic atom-rich layer is 100 %. Owing to the ferromagnetic atom-rich layer as described above, the exchange coupling force, which is generated between the ferromagnetic atom-rich layer and the recording layer, is larger than the exchange coupling force which is generated between the magnetization-stabilizing layer and the recording layer of the conventional magnetic disk ~~shown in Fig. 18~~. Therefore, the thermal stability of the recording layer is further enhanced as compared with the conventional technique, making it possible to realize further advanced high density recording.

[0016] As a result of investigations performed by the present inventors, it has been found out that the exchange coupling between the recording layer and the magnetization-stabilizing layer can be remarkably improved by intervening a several-atoms-layered Co layer at an interface between the Ru layer (non-magnetic layer) and the recording layer and/or an interface between the Ru layer (non-magnetic layer) and the magnetization-stabilizing layer of the magnetic disk having the conventional type structure ~~shown in Fig. 18~~. The layer to be intervened at the interface is not limited to Co, which may be composed of a material having a high ferromagnetic atom concentration as compared with the recording layer, and

which may be constructed with a variety of substances capable of improving the exchange coupling between the recording layer and the magnetization-stabilizing layer as described later on. That is, when the magnetic recording medium is provided with the magnetization-stabilizing layer, the exchange coupling force between the recording layer and the magnetization-stabilizing layer can be improved by positioning the ferromagnetic atom-rich layer at the interface. In this specification, the ferromagnetic atom-rich layer is also referred to as "enhancing layer", because the ferromagnetic atom-rich layer is also provided with the function to enhance the exchange coupling between the recording layer and the magnetization-stabilizing layer when the magnetization-stabilizing layer is provided.

[0017] According to the knowledge of the present inventors, the reason why the ferromagnetic atom-rich layer, i.e., the enhancing layer, which is positioned between the magnetization-stabilizing layer and the recording layer, successfully improves the exchange coupling between the recording layer and the magnetization-stabilizing layer is as follows. In the case of the conventional type magnetic disk~~ shown in Fig. 18~~, the recording layer of CoCrPtB and the magnetization-stabilizing layer of CoCrPtB are stacked with the Ru layer intervening therebetween. In this case, the recording layer and the magnetization-stabilizing layer effect the exchange coupling via the Ru atom layer. It is considered that the exchange coupling is effected on the basis of the fact that the electron orbits are coupled between the Co atoms in the recording layer and the magnetization-stabilizing layer via the Ru atoms. Such a coupling is also found, for example, in the coupling in an artificial lattice of a GMR head.

[0030] The magnetic recording medium of the present invention comprises the lattice spacing-adjusting layer which is formed between the underlying base layer and the recording layer and which is formed of the ferromagnetic material to make control so that the difference in lattice spacing between the lattice spacing-adjusting layer and the underlying

base layer is smaller than the difference in lattice spacing between the recording layer and the underlying base layer. The lattice spacing-adjusting layer as described above mitigates the lattice strain between the underlying base layer and the recording layer, and the crystalline orientation of the recording layer is improved thereby. Accordingly, it is possible to increase the coercive force of the recording layer. The magnetic recording medium as described above is formed of the ferromagnetic material in the same manner as the magnetization-stabilizing layer of the in-plane magnetic recording medium having the conventional type structure~~ shown in Fig. 18~~. Therefore, it is possible to stabilize the magnetization of the recording layer. That is, the lattice spacing-adjusting layer has a function to stabilize the magnetization of the recording layer, in addition to a function as a seed layer to act so that the lattice strain between the underlying base layer and the recording layer, i.e., the discrepancy of lattice spacing is mitigated. Therefore, the high density recording can be put into practice by using the magnetic recording medium of the present invention, because the minute magnetic domain formed in the recording layer can be stably retained. In the present invention, the term "lattice spacing" means the lattice spacing on the orientation plane.

[0035] It is desirable for the magnetic recording medium according to the second aspect of the present invention that a relationship of Msl > Ms2 is satisfied provided that saturation magnetization of the lattice spacing-adjusting layer is represented by Msl, and saturation magnetization of the recording layer is represented by Ms2. For this purpose, it is desirable that the lattice spacing-adjusting layer is formed so that a ratio of magnetic atom contained in the lattice spacing-adjusting layer is larger than a ratio of magnetic atom contained in the recording layer. Accordingly, it is possible to further increase the exchange coupling force between the recording layer and the lattice spacing-adjusting layer. In the case of the conventional type medium~~ shown in Fig. 18~~, the recording layer and the magnetization-stabilizing layer are composed of the same material, in which the composition

and the crystal structure are also the same. The recording layer and the magnetization-stabilizing layer are subjected to exchange coupling via the Ru layer. It is considered that the exchange coupling is based on the fact that the electron orbits are coupled to one another for the Co atoms in the recording layer and the magnetization-stabilizing layer by the aid of the Ru atoms. In the present invention, the ratio of the magnetic element in the lattice spacing-adjusting layer is made higher than the ratio of the magnetic element in the recording layer to increase the amount of magnetic element which contributes to the exchange coupling. Therefore, the exchange coupling force between the recording layer and the lattice spacing-adjusting layer is increased as compared with the exchange coupling force between the recording layer and the magnetization-stabilizing layer of the conventional type medium ~~shown in Fig. 18~~. Accordingly, it is possible to improve the thermal stability as compared with the conventional type medium ~~shown in Fig. 18~~.

[0043] Each of the magnetic recording media according to the first and second aspects of the present invention has a magnetic characteristic which is represented by a hysteresis loop as depicted by a magnetization curve as shown in Figs. 4 and 16. The following description will be made on the basis of a case of the magnetic recording medium according to the first aspect. However, an equivalent relationship is also affirmed between the lattice spacing-adjusting layer and the recording layer of the magnetic recording medium according to the second aspect. In the hysteresis loop shown in Fig. 4, a point, at which a rate of change of magnetization with respect to the external magnetic field exhibits a local maximum when the external magnetic field is lowered after magnetization of the magnetic recording medium is saturated, exists in an area of positive magnetic field. When the magnetization of the magnetic recording medium is saturated, both of the magnetizations of the recording layer and the ferromagnetic atom-rich layer (or the lattice spacing-adjusting layer) are parallel. The magnetization of the ferromagnetic atom-rich layer (or the lattice

spacing-adjusting layer) is inverted due to the exchange coupling force exerted between the ferromagnetic atom-rich layer (or the lattice spacing-adjusting layer) and the recording layer in the area in which the rate of change of magnetization exhibits the local maximum as the external magnetic field is lowered. In the residual magnetization state, the thermal stability of the magnetization of the recording layer is improved owing to the exchange coupling force as described above. Further, a minor hysteresis loop as shown in Fig. 4 may be observed in the area in which the rate of change of magnetization is locally maximized. The minor hysteresis loop is shown in Fig. 5A. The exchange coupling magnetic field H_{ex}, which is determined from the central point of the minor hysteresis loop, is increased in accordance with the increase of the exchange coupling force between the ferromagnetic atom-rich layer (or the lattice spacing-adjusting layer) and the recording layer. Therefore, it is indicated that the larger the exchange coupling magnetic field is, the larger the thermal stability is. The exchange coupling magnetic field H_{ex} is not less than 1 kOe, preferably not less than 1.5 kOe, which is remarkably larger than that of the conventional type magnetic recording medium ~~shown in Fig. 18~~. Therefore, it is appreciated that the magnetic recording medium of the present invention is excellent in thermal stability.

[0048] Fig. 1 shows a cross-sectional structure of a magnetic disk according to a first embodiment.

Fig. 2 shows a cross-sectional structure of a modified embodiment of the magnetic disk according to the first embodiment.

Fig. 3 shows a cross-sectional structure of another modified embodiment of the magnetic disk according to the first embodiment.

Fig. 4 shows a graph illustrating a hysteresis loop (major loop) of the magnetic disk according to the first embodiment.

Fig. 5A shows a minor loop of the hysteresis loop shown in Fig. 4, and Fig. 5B shows a minor loop of a hysteresis loop of a magnetic disk concerning Comparative Example 1.

Fig. 6 shows a schematic cross-sectional structure of a magnetic disk according to a fourth embodiment of the present invention.

Fig. 7 shows a cross-sectional structure of the magnetic disk concerning Comparative Example 1.

Fig. 8 shows a schematic arrangement of an exemplary magnetic recording apparatus according to a second embodiment of the present invention as viewed from a position thereover.

Fig. 9 shows a sectional view as viewed in a direction of A-A' illustrating the magnetic recording apparatus shown in Fig. 8.

Fig. 10 shows a schematic sectional view illustrating a magnetic disk produced in a third embodiment of the present invention.

Fig. 11 shows graphs illustrating a hysteresis loop (major loop) of the magnetic disk shown in Fig. 10, and a magnified view of a minor loop of the hysteresis loop.

Fig. 12 shows a schematic sectional view illustrating a modified embodiment of the magnetic disk according to the third embodiment of the present invention.

Fig. 13 shows a schematic sectional view illustrating another modified embodiment of the magnetic disk according to the third embodiment of the present invention.

Fig. 14 shows a graph illustrating a hysteresis loop (major loop) of a magnetic disk according to a fourth embodiment.

Fig. 15 shows a graph illustrating a relationship between a film thickness of a lattice spacing-adjusting layer and a coercive force of a recording layer and a relationship between the film thickness of the lattice spacing-adjusting layer and an exchange coupling magnetic field concerning the magnetic disk according to the fourth embodiment.

Fig. 16 schematically shows a minor loop of the hysteresis loop shown in Fig. 2.

Fig. 17A shows a graph illustrating the change of exchange coupling energy with respect to the ferromagnetic atom (Co) concentration of a ferromagnetic atom-rich layer, and Fig. 17B shows a graph illustrating the change of (Ku•V)/kB•T with respect to the ferromagnetic atom (Co) concentration of the ferromagnetic atom-rich layer.

~~Fig. 18 shows a sectional view illustrating a structure of a conventional magnetic disk.~~